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ABSTRACT

This study documents text-based science instruction as it actually occurred in the classroom of a fifth-grade teacher teaching the unit on light found in "Exploring Science" by M.K. Blecha, P.C. Gega, and M. Green (1979, Laidlaw Brothers). The study, focusing on the nature of and reasons for the teacher's successes and failures, examined the planning process, actual instruction, students' learning and the textbook used. Although many excellent teaching practices were observed (such as providing hands-on experiences and integrating science with other areas), only one-third of the students understood certain basic ideas about light/seeing at the end of the unit. Two serious problems related to their lack of understanding were identified. First, the textbook did not describe how we see in a way adequate to alter the ideas of children strongly committed to their misconceptions. In addition, the teacher's guide did not prepare the teacher for the existence of those misconceptions or suggest a strategy adequate for dealing with them. The second problem concerned the teacher's questioning techniques. Correct answers were sought and incorrect answers were not used to diagnose students' misconceptions. It is indicated that both of these problems can be solved and teachers can be helped to understand students' misconceptions and change them successfully. (JN)

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Research Series No. 129

# STUDYING LIGHT IN THE FIFTH-GRADE: A CASE STUDY OF TEXT-BASED SCIENCE TEACHING

Lucille A. Slinger, Charles W. Anderson,
and Edward L. Smith

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## Abstract

This is a case study of one fifth-grade classroom teacher using the Laidlaw Brothers Exploring Science textbook. The teacher was an excellent teacher who was extremely successful at organizational and affective levels, but, at best, only partially successful in facilitating learning of scientific content. The most severe problems in this case seem to lie not so much with the teacher as with the textbook she was using, which did not prepare her to deal with the misconceptions that severely hindered student learning.

# STUDYING LIGHT IN THE FIFTH GRADE

## A CASE STUDY OF TEXT-BASED SCIENCE TEACHING[1]

Lucille A. Slinger, Charles W. Anderson, and Edward L. Smith[2]

This is the story of how one fifth-grade teacher taught the unit on light from her text-based science program. In one way it is a story of success; Ms. Rosal[3] was a highly skilled teacher who made the unit come alive for her students by adding a variety of exciting activities. However, this is also a story of failure: Only one-third of the students in Ms. Rosal's class understood certain very basic ideas about how people see at the end of the unit. In this paper we attempt to describe the nature of, and the reasons for, Ms. Rosal's successes and failures.

Like most elementary school science teachers (Smith, Note 1), Ms. Rosal used a textbook. This study documents the nature of textbased science instruction as it actually occurred in her classroom. We believe that Ms. Rosal's successes and failures raise important issues regarding how elementary school science textbooks are designed and used.

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[2]Lucille A. Slinger worked on the Elementary Science Project as a graduate assistant. She is now a teaching assistant for MSU's Academic Learning Teacher Education Program. Charles W. Anderson and Edward L. Smith coordinate that project. Anderson is an assistant professor of teacher education and Smith an associate professor of administration and curriculum, both in MSU's College of Education.

[3]Not her real name. Students' names in this paper are also pseudonyms.

This study complements previous case studies of activity-based elementary science instruction (Smith & Sendelbach, 1982; Smith & Anderson, Note 3). It is part of a larger study, and reports on other aspects of the study are also available. Anderson and Smith (Note 4) describe student conceptions of light in detail and present results from tests on light given both before and after instruction in Ms. Rosal's class and four other classes. Eaton, Anderson, and Smith (in press) describe the reactions of six students to classroom instruction about light.

## Method

Although ethnographic techniques were used for this case study, the primary perspective used for interpreting the actions of Ms. Rosal and her students was that of cognitive science or information-processing psychology. Research on teacher planning and teacher thinking from this perspective is reviewed by Clark and Yinger (Note 2). There is a large body of work on student conceptions of scientific topics based on this perspective (e.g., Nussbaum & Novak, 1976; Erlwanger, 1975; Erickson, 1979; Davis, 1981.

Ms. Rosal used the fifth-grade Exploring Science textbook (Blecha, Cega, & Green, 1979). This study focuses on Unit Four, a three-chapter unit about light. The text was analyzed before the case study began. The case study focused on (a) Ms. Rosal's planning process, (b) actual instruction, and (c) the students' learning. Methods used for each part of the study are described below.

### Curriculum Materials Analysis

Unit Four was analyzed as a series of academic tasks to be accomplished by the students. Each task was described in terms of format for instruction (whole class, small group, etc.), expected teacher behavior, expected student

behavior, information content, and science process skills addressed (Landes, Smith, & Anderson, Note 5). This analysis was done prior to actual classroom observation. It served as a basis for interpreting planning and actual instruction and formulating a test of student learning. It sensitized the observer to modifications in or deviations from the program.

Teacher Planning

Ms. Rosal's planning was investigated through collection of lesson plans and related documents, interviews and videorecordings of two planning sessions.

Her initial planning for the unit was videotaped during a 45-minute free period that she normally used for planning. The following day she described her thoughts during a stimulated recall session (i.e., she described her thoughts as she watched the videotape replayed). The procedures for the video-recording and stimulated recall were based on the work of Smith and Sendelbach (Note 6). A second videorecording was made of Ms. Rosal's planning for Chapter 3. Rather than having a separate stimulated recall session, she verbalized her thoughts aloud during video recording as she planned and answered questions immediately following the planning process.

Weekly and daily plans were documented by making copies of her planning book and writing down comments she made about planning before, during, or following instruction. The observer also probed for rationales whenever instruction deviated from the teacher's lesson plans.

Observation of Instruction

Classroom observation began prior to the teaching of the light unit to acclimatize the teacher and students to the researcher's presence and the audiorecording of class lessons. It also provided preliminary information about the classroom operations and science lesson routines. The observer generally entered the room 10 to 15 minutes before the science lesson was to

begin. The observer assumed a nonparticipant-observer status, although she occasionally talked to individual students during individual or small-group activities.

Detailed narratives of each lesson were dictated using the audiorecordings and field notes as data sources. These narratives were analyzed to determine student tasks performed and knowledge content addressed, using procedures parallel to those used for the curriculum materials analysis. Procedures are described in Hollon, Anderson, & Smith (Note 7).

### Student Learning

Student learning was assessed with tests given before and after instruction on the light unit (for further information, see Anderson & Smith, 1982). The changes in student understanding of light were also traceable by the students' responses recorded during instruction, collected copies of seatwork, teacher-given quizzes, and the final unit test.

## Context

### The Setting

Ms. Rosal's classroom is situated in a small town near one of Michigan's larger cities. Her students'parents were mainly blue- or white-collar workers in factories, businesses, or the university in a nearby city. The school, with over 300 students in grades K-5, had three fifth-grade classrooms located around a shared activity room.

Ms. Rosal's classroom had a rich array of materials and a friendly and appealing atmosphere. It appeared to offer an environment that encouraged successful teaching and learning.

## Students

There were 22 students in Ms. Rosal's class. She described the group as rather transient, with only a few students who had been in the school since kindergarten. There had been a student turnover rate of over 50% in her classroom between September and January. Ms. Rosal tried to mold the students into a harmonious group. She mentioned how difficult this was in the fall when a new student arrived every other week. Enrollment was stable by the time the case study began in mid-February. Ms. Rosal described her students as covering a wide range of ability and maturity, from the academically talented to one student who had been sent back from the middle school.

## The Teacher

Ms. Rosal was teaching fifth grade for the first time after 12 years at the school as a primary grade teacher and two years as an eighth-grade math teacher in another district. She requested the move to fifth grade.

Ms. Rosal held a B.S. in elementary education with a math-science major. Her favorite subject was, "mathematics because of its preciseness!" In rank ordering subjects according to her own feelings of success in teaching, she stated, "Science and social studies come after reading and math and handwriting because those things are basic tools for everything else." She put science before social studies and language arts last.

## Science Lessons

Science was taught on Monday, Wednesday and Friday afternoons. It always came after a quiet-down period of 10 to 15 minutes, following the noon recess, during which Ms. Rosal read to the students. During the six-week observation period, a special school assembly and one special make-up lesson were the only things that caused a change in the scheduled science-lesson times. Lessons ranged from 35 to 69 minutes and averaged 49 minutes.

## Planning

Many of the most important characteristics of Ms. Rosal's teaching were determined before she began the first lesson of the unit. Her planning for the year began before school started in September, she engaged in unit planning in February, and weekly and daily planning continued throughout the unit, which she taught in March and April. Ms. Rosal's planning at each level is described below. A commentary focusing on characteristic traits of planning at each level accompanies each description.

### Long-Range Planning

Ms. Rosal's planning for science instruction began in early August when she was told she would be teaching fifth grade. She said,

> My first move was to close out my second-grade room and move into the fifth-grade room. At the same time I picked up the curriculum guides and all the textbooks. Then leaving and taking them home with me and the cottage where I began my perusing, I guess that's the best word--generally going through the books, finding out what was contained in them and the district curriculum guides for fifth-grade level and to figure out what I was going to do and how I was going to do it.

She knew the district had adopted the Exploring Science text the previous year and stated that the "curriculum guide was molded by the textbook and we were expected to follow it." She reviewed the units in Exploring Science and decided to "start at the beginning and just go straight through the text." This was her rationale:

> If you don't have any logical reason for juggling the units, then why do it? I still think, well, somebody must have known something when they wrote the text. Laidlaw is an old established textbook company and if they include something in a text, it must be pretty well written.

She described the process she used to familiarize herself with the science program as follows:

> I paged through it (the teacher's guide), read parts, read chapter headings; tried to figure out how the book was organized, like the (chapter) review pages, unit tests published in it, review summaries at the end units, sample answers for student questions and background information for the teacher

Commentary on long-range planning. During long-range planning, Ms. Rosal focused on sequencing, time, and content for science instruction. She emphasized her trust in the quality of the textbook and district guidelines for instruction. She made few specific instructional decisions at this time.

Unit Planning: Constructing a Web of Meaning

Having used the text for five months prior to planning for the light unit, Ms. Rosal had established a routine that combined unit planning with planning for the first week of instruction on the unit.

She began by having a relatively cleared teacher's desk with her teacher's guide, a stack of science books she had used in previous years, a calendar, and a plan book opened to the new week. She marked off time for science in the appropriate Monday, Wednesday, and Friday time slots and added any outside activities and events that were to occur that week.

She opened the teacher's guide to the unit on light, then wrote herself a note to check out science books on light. She clipped the note to the current week's schedule. She planned to check out the books during her class' regular weekly library hour or ask the librarian to do it for her. She stated that the librarian was a good resource person who often suggested films or books available on a specific topic if asked.

These outside library books were important because there were not enough textbooks for every child to have one; the textbooks were shared with another fifth-grade class. The library books would be available for students who finished their regular reading assignment before other students.

As Ms. Rosal began her unit planning, her thoughts were, "The first thing I need to do is take a look at exactly what the unit is about." She began by reading the notes at the bottom of the opening pages for the unit in the teacher's guide. These notes outline the procedures for introducing the unit,

main concepts of the chapter, performance objectives, and vocabulary words. She underlined the vocabulary words as she read. She next read the introductory cartoon in the student-text portion of the teacher's guide. She paused to think about the questions presented in the cartoon, then proceeded to read the rest of the teacher notes for Chapter 1. As she read the notes, she underlined words she did "not know the meaning of right at that time." For Chapter 1, she underlined bioluminescence, photoelectric cell, bending, and bouncing.

When she had read all the teacher notes for Chapter 1, she checked the clock to note how long it was taking her, then paged through the chapter again as she thought about what she would do during the first week of teaching the unit, "realizing the main thing for me in planning out my lesson for next week right at this point was to make sure there was nothing absolutely off the wall that I was going to need to do the experiments." She proceeded to read the Find Out[4] activities for Chapter 1 and then turned to the back of the teacher's guide to the section on instructional materials and teacher background information for Chapters 1, 2, and 3 of the unit.

As she read the teacher background information for the light unit, she again underlined words and such phrases as "speed of light." She highlighted these terms because,

> I would need to be familiar with them and I want the students to at least be aware of them. I am not really sure in my own mind how much I would expect them to actually be able to use the term, but I want them firm in my memory.

She made notes about things her students might do, such as "oil a piece of brown paper and let the kids see light shining through it because we did talk about early pioneers in our history." (This activity's purpose would be to

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[4]In Exploring Science there are a number of activities or experiments described that a teacher might wish to do with his/her class. These are usually less than a page, set off in a box, and given the heading "Finding Out"

demonstrate translucence. Ms. Rosal had told her students that the pioneers used oiled paper to cover windows.) She noted special projects, such as a report on Sir Issac Newton, that she might want to have her gifted students do. She also noted in Chapter 2 a possible art activity related to the spectrum and use of colors. She said that she had no particular activity in mind at that point, but wanted a reminder for later. Other salient topics Ms. Rosal noted were the differences between fluorescent and incandescent light and how the three primary colors can produce all colors there are.

As she read the teacher's background information for Chapter 3, she underlined the names of the eye parts and special terms. She thought about how she and her class had done a special study on the ear earlier that year because one of her students was partially deaf. A county nurse had been invited in for that session, and Ms. Rosal recalled how interested the students had been. She thought they would probably have a similar interest in the eye. She wrote "pinhole camera" as a possible activity showing how the eye works. This was an experience she recalled from the natural science course she had in college.

She finished reading the teacher background information, then turned to the district film catalog and searched for possible films to use with the unit. Her thoughts were, "I'm probably already too late for this year, but if I get on the ball next year and order the films in September or October, then I may get one." She did not find any films she wished to order, so decided to ask the librarian if she knew of any about light she might use.

Commentary on unit planning. The fact that Mrs. Rosal engaged in unit planning is itself significana. Her concern with the meaning of the unit for herself and her children is not characteristic of all teachers (cf., Smith & Sendelbach, 1982). The fact that the visible products of her unit planning

consisted only of a few notes and underlined words does not diminish its importance. Ms. Rosal was constructing a web of meaning, a conceptual network that she intended to share with her students. This web of meaning encompassed not only science, but social studies, art, and the personal needs of her students. The nature of Ms. Rosal's unit planning demonstrates her commitment to her students and their learning.

What Ms. Rosal did not do, however, is as significant as what she did. She did not question the appropriateness of the content or the instructional strategy of the text, and she did not make any attempt to assess her students' understanding of light before she began planning the unit, even though she had never taught the unit before. She was not unusual in this respect. We have never seen a teacher who did assess student understanding before starting to teach. Ms. Rosal's failure to test or question her implicit assumptions about what her students knew and understood would ultimately have serious effects on her students' learning.

Weekly Planning: Constructing a Sequence of Activities

Ms. Rosal "officially" began her planning for the first week's instruction by returning to the student test and, as she said, "really reading it." She described her established routine for instruction for each science chapter as follows:

> One of my first assignments is to ask the students to read the chapter--read it for one entire period--and ask them to make a list of definitions for the vocabulary words I give them out of their science book.

She wrote this plan in abbreviated form in her plan book: "Read 145-157 and definitions." She began a list of woreds she wished her students to define, but did not complete the list until she did her daily planning. The list of words at this point read, "opaque, scattering, translucent, transparent."

She then began to review the Finding Out activities, which she referred to as experiments because "doing a science experiment is much better and much more fun than doing an activity. Kids like an experiment better than an activity." In her plan book she described the second lesson as "discussion and experiments." After reviewing all the Finding Out activities in Chapter 1, she decided they could and would do them all, knowing that they would probably not be completed during the first week of instruction. She regarded the experiments as important.

> To have the kids see for themselves. They learn by doing. If they get to do something, then they really like it and it gives them a reading purpose. They want to find out why things happen the way they saw them.

While she reviewed the experiments, she noted materials that would be required and decided that no special equipment was needed that was not already available at school.

As Ms. Rosal read through Chapter 1, she decided that bouncing balls off the chalkboard would be a good "sparking activity," a way "to get the attention of the students with some clever idea and make them wonder what that has to do with science." She wanted this "sparking activity" to demonstrate how light reflects off different surfaces.

In addition to the teacher's guide, she used reference resource books from the library and old texts that were in the fifth-grade classroom to clarify ambiguous terms, concepts, or experimental procedures. She also used these materials during daily planning if she did not have time during weekly planning.

Ms. Rosal did not try to be too specific in her weekly planning.

> I sort of block it in generally but don't get down to specific planning until the day before I actually teach it. I found that it doesn't pay to plan early. Sometimes you don't get that far and then it also depends on how the lesson goes with the kids. Flexibility is the name of the game.

Commentary on weekly planning. Ms. Rosal's weekly planning was the first level of planning that resulted in a definite written product: sketchy lesson

plans in her plan book. Clearly, though, the written plans were notes to herself, reminding her of much more elaborate plans she carried in her head. By the time she completed weekly planning, she had made many of her most important instructional decisions for the week. She had constructed a sequence of activities that would help her share concepts of light with her students. Daily planning and teaching were devoted largely to implementing the decisions she had made during weekly planning.

Daily Planning: Preparing Materials

Daily planning occurred whenever Ms. Rosal found the time. Sometimes it was during recess break, the night before a lesson, after school, or during school when students were engaged in quiet seatwork. The daily planning process involved reviewing and rereading the student text, collecting and organizing the materials needed for the lesson, and readjusting the weekly plans if necessary. She usually had all materials ready before science class started, but on two occasions she was observed collecting materials during science lessons (while the students were engaged in individual activities). She generally tried the experiments and previewed films prior to actual instruction. On the occasions when she had not done this, she told her students it was new for her too.

## Instruction

Two key instructional episodes are described below to provide an in-depth view of Ms. Rosal's teaching. The patterns we noted in these episodes were consistent across her lessons, as supported by a brief description of the other lessons on light. Ms. Rosal's students' understanding of light before and after instruction is also described.

Pretest Results: What Ms. Rosal Did Not Know

Our pretest results indicate that Ms. Rosal's students began the unit with several important misconceptions about light and how we see that can interfere with learning. For the purpose of this paper we will focus on the most basic of these misconceptions: Students' ideas about how light helps us to see. The Exploring Science textbook states that we see because "light bounces off an object to our eyes." Only one of the 19 students in Ms. Rosal's class understood this idea at the beginning of the unit. Most of the other students held misconceptions that could be contrasted with the textbook statement in two respects:

1. Rather than thinking of light as bouncing off objects, they thought of light as "shining on" or "brightening" objects. That is, they thought of light as merely a condition that makes objects visible.

2. They thought of seeing as a process in which objects are directly perceived; they believed that our eyes "see" or "focus on" the objects themselves rather than detecting light which bounces off objects. (For a more thorough discussion of these and other student misconceptions, see Anderson & Smith, Note 4).

Thus, Ms. Rosal began the unit facing a challenge that she did not perceive: Most of her students would understand the light unit only through a process of conceptual change, in which they abandoned their misconceptions and accepted the textbook's explanation of how we see. The text, however, is inadequate for this purpose. Even though large portions of the text are incomprehensible to students believing the misconception described above, the text contains virtually no material that would help such students to abandon their misconception. (For an analysis of the text, see Eaton, Anderson, & Smith, in press).

The First Lesson

Just as the beginning of a story initiates the reader into all that follows, Ms. Rosal's introductory lesson for the unit is selected as a key episode of instruction. This episode illustrates her adaptability and ingenuity in instruction and the limitations of her responses to her students' misconceptions.

Ms. Rosal began this lesson by having the students clear their desks while she plugged in a filmstrip projector, pulled down the film screen at the front of the room, and turned off the room lights. She then announced the lesson plan to the students:

> We are going to start our new unit of science. I thought as a way of illustration, to get you started with what it is going to be about, I would just show you a couple of things and talk about a couple of things first.

All the students quietly listened and watched except for three, who were secretly playing with fist-fulls of pencils at their desks. She reminded the students of the pretest taken for the research project.

Ms. Rosal continued her introduction, telling the students about her perceptions of the topic:

> I found in doing some work ahead of time, that this unit certainly contained some things that had to do with light that I didn't think had to do with light, and I didn't think they even had to do with science. So I hope that it turns out to be one of the chapters of your science book that turns out to be really fun for you and interesting and that you do learn some new things.

This was immediately followed by the first activity. As Ms. Rosal flipped on the projector, shining a light beam on the screen, she told the students,

> Right now I have the filmstrip projector with a light. I wanted to have a sharp, direct, bright light to shine on the movie screen. I want you to take a look at what happens when I shine it over here.

Ms. Rosal moved the projected light beam over a black-background map of the world. At this point she realized the desired effect was not obvious, so she directed Sheila to pull the drapes and Eric to turn out the lights in the

activity room.[5] While Eric and Sheila carried out her request, Ms. Rosal kept the other students actively observing by creating a shadow on the screen with a pen.

After Sheila and Eric had returned to their seats, Ms. Rosal directed the students to "look at the light." She directed the beam of light to the movie screen, then the black-background map, the brown chalkboard, and even to the brown, wood-grained classroom door. She moved back and forth between the different surfaces several times, then stopped with the beam of light on the film screen and asked the students, "What do you notice?"

Several students were talking with their neighbors in response to the question and Jeff announced without solicitation, "The room gets darker." Ms. Rosal called on Donnie, who had raised his hand. He said, "Well, when it gets into the white area some of the light reflects off the white and shows more light."

Ms. Rosal asked Donnie to rpeat his answer because "some people are concerned about the activity room rather than what's going on in here." The students seated near the activity room picture windows had been distracted by curious students from another fifth-grade class who paused to look into Ms. Rosal's room as they passed by.

Donnie restated his answer more confidently, "When you shine it on the white, the white screen reflects more light and the other dark colors absorb it."

"How can you tell that, Donnie?" asked Ms. Rosal.

"Because you can see," said Donnie, "it's all over the ceiling and around."

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[5]The three fifth-grade classrooms opened onto a common activity room, which was dominated by a table and chairs. Ms. Rosal's classroom had large windows through which the students could see into the activity room.

Ms. Rosal then moved the light beam back to the brown chalkboard asking, "When it is shining on the brown board, what about the rest of the room?"

Several students answered, in chorus but not in unison, "It's darker," and Ms. Rosal added, "compared to when it's shining on the white board."

Ms. Rosal again moved the light beam back and forth between the different surfaces, allowing the students to quietly comment to their neighbors. Students were heard comparing when it was darkest or lightest.

Ms. Rosal said, "These are some differences," and moved the light beam over to the side of the room so that it shone through the picture window to the far wall of the activity room. She asked the students, "What is happening now?" The students giggled and laughed a little at first, then began talking with each other about the light passing through the window. They seemed very excited and protested when Ms. Rosal returned the light beam back to the front of the room. Ms. Rosal told them, "We're disturbing the other class and they are wondering what's happening in here."

The class moved rapidly through several additional activities in which they made shadows on the screen with a pointer, a pencil, and their hands. The students in general seemed excited as Ms. Rosal flicked off the projector and asked Theresa to turn on the classroom lights, signaling an end to the activity.

The next activity for the lesson required different materials. Ms. Rosal had commented during an initial interview and on two other occassions, "The major problem in teaching science is the lack of materials." For the next activity she planned around this problem by using a sponge die from a previous math lesson and relying on the students to provide additional materials.

Ms. Rosal went to her desk and picked up the sponge die. As she walked to the front of the room, she told the students that she didn't have a ball and asked if any of them did. Immediately, several students opened their desks

and rummaged through them, producing a tennis ball, a small high-bounce ball, and a jacks ball. Ms. Rosal told the students, "I want you to just observe, watch what I'm going to do. Don't say anything, just watch."

She proceeded to move several feet away from the chalkboard and threw the die and the balls at the film screen, and at the chalkboard from three different locations (left, center, right). She pointed out to the students where she had stood by walking to each of the positions again as she asked, "What did you observe?"

Theresa said, when called upon, "When you threw it against the screen it didn't bounce as hard."

Ms. Rosal asked, "Did any of them bounce as hard?" The students answered "no," as Ms. Rosal called on Joey.

Joey said, "When you threw it from over there it hit the chalkboard and went to Carol," a correct observation. Paul pointed out that when Ms. Rosal threw it from the left side it came over to him on the right side. Sheila said, "When you threw it straight it bounced straight back." Mike said, "Every direction you face, that's the way it bounces back." Other students told Mike, "no" or "you're wrong," and the class became involved in a debate over Mike's observation.

Ms. Rosal returned the balls to their owners as she summarized both activities, focusing on the main point of the chapter, which she considered to be how light bounces. She then gave the students directions for the next activity.

> Okay. We are studying light. We are going to be studying differences in the way things bounce. The way things bounce, and light bounces, we are going to be studying why it depends on what it bounces off of, and that's why I showed the balls bouncing off the screen and the chalkboard and light from the projector bouncing off the screen, chalkboard, the dark map, and the glass.
>
> I would like to have you, right now, read in your science book the first chapter on the unit of light. And I want you, at the end of that

> chapter, to get a piece of yellow paper or your own paper and copy down these words (she pointed to the list of words on the chalkboard; opaque, translucent, transparent, lens, convex lens, bouncing, scattering, bending, image, reflection), and from your reading I want you to try to write a definition for these words, something that will help you understand, show that you know what these words mean. Anyone know what any of them mean right now?

After several students had offered their own definitions for the words on the board, Ms. Rosal closed the discussion by telling the students, "You do have some good understanding of these words already and you are going to get help, hopefully, to clear up some of them, to make them more definite."

She then asked a student to pass out science books to the students who did not have their own copies. The room noise increased as the students opened their desks to get their paper and science books. Ms. Rosal completed her directions with this afterthought, "Your definitions, when you get done, keep them in your science book."

During the next 28 minutes most of the students read the chapter and completed the definitions, working silently at their desks with occasional help or questions from Ms. Rosal. A few students spent the time taking a make-up test on electricity, and a few others did not finish. Ms. Rosal completed the science lesson by showing the students several books on light that she had checked out for them from the library and telling them that if they didn't get their definitions finished today they should complete them by Friday, "when we'll talk about it and what you found out in your beginning readings of the chapter."

Commentary on the First Lesson

The first lesson illustrates a number of patterns that were characteristic of Ms. Rosal's teaching throughout the unit. Three of those characteristics are discussed below.

1. Adaptability and ingenuity. Ms. Rosal frequently thought of ingeneous activities like the opening demonstration, and she showed considerable skill in adapting these activities to conditions in her classroom. Although she planned these activities in advance, she responded to her students as the lesson progressed, changing her plans when she thought it appropriate. She kept the lesson fast-paced and interesting, and she managed her students' behavior well.

Although we have characterized Ms. Rosal's instruction as text-based, her students actually spent more time over the course of the unit engaged in demonstrations and experiments (25%) then they did in reading the text (17%).

2. The chapter cycle. Ms. Rosal's planning and teaching for each chapter were governed by a regular five-part cycle:

1. A motivational demonstration, which Ms. Rosal called a "sparking activity."
2. Silent reading and writing of definitions.
3. Conducting the experiments described in the text.
4. Additional activities from outside sources.
5. Chapter review and quiz

The first lesson contained the first two parts of the cycle for Chapter 1. This cycle was disrupted only once during the unit, when a substitute teacher misinterpreted Ms. Rosal's very sketchy written plans for Part 2 of the cycle for Chapter 3. (The plans read in their entirety, "Read 181-188, eye problems, animal eyes.") The substitute had the students read aloud, rather than silently, and the lesson was not completed. This made it necessary to complete the reading silently after Ms. Rosal returned, then delay some of the experiments until after the unit review and test (which she wanted to complete before the end of the grading period).

This chapter cycle accomplished three things for Ms. Rosal. First, it simplified her planning, giving her a sequence of steps and procedures for deciding what to do. Second, it assured virtually complete coverage of the material in the text. (Ms. Rosal omitted nothing from the teacher's guide during the unit except a few optional activities.) Finally, the chapter cycle assured that the students would learn science in a variety of ways through such activities as experiments, class demonstrations, silent reading, and written work. Ms. Rosal's chapter cycle did not, however, provide her with a reliable way of detecting or dealing with her students' misconceptions.

3. Failure to address student misconceptions. During the first lesson Ms. Rosal effectively addressed one of the two misconceptions described in the section on pretest results, though she did not realize her students held that misconception. She demonstrated to her students that ordinary objects reflect light instead of being brightened, as most of the students seemed to think. However, she never addressed the other misconception; she never mentioned that we see reflected light rather than perceiving objects directly. This failure may seem insignificant in a lesson where vision was not discussed. However, as the coin demonstration described below as part of the third lesson illustrates, Ms. Rosal did not emphasize the role of reflected light even in situations where it was crucial to her students' understanding.

The Second Lesson

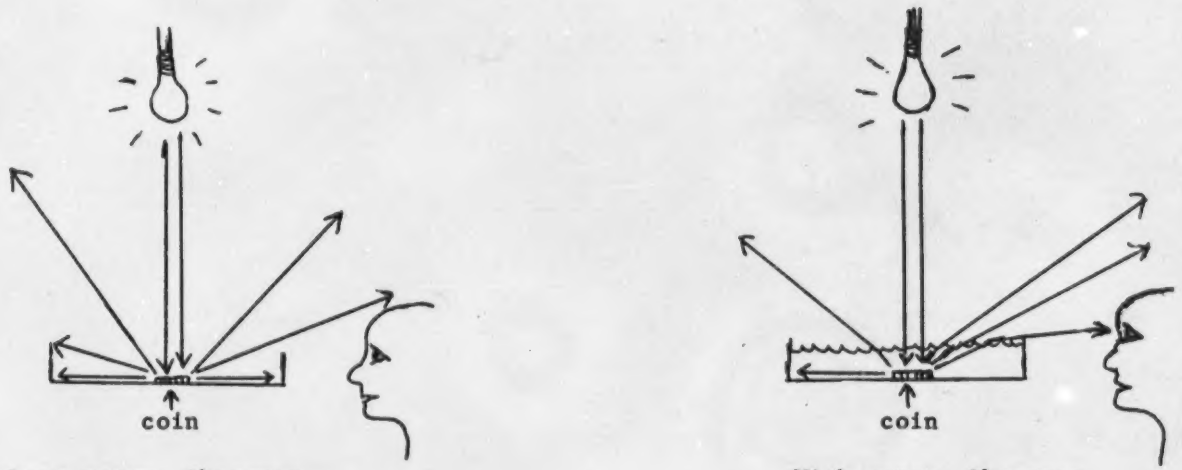
Lesson 2 began with a discussion of the reading, which focused primarily on the definitions of vocabularly words described in the text and the questions in the chapter. The four experiments described in the chapter were each demonstrated by small groups of students with the teacher's assistance, while another student read directions from the text. The lesson ended with an application exercise in which Ms. Rosal displayed transparent cellophane wrap,

translucent wax paper, and opaque aluminum foil and discussed with the students how light interacts with each.

The Third Lesson

The third lesson began with a short quiz in which students looked at 10 objects presented by Ms. Rosal and classified each as transparent, translucent, or opaque. The students exchanged papers and reviewed each answer through discussion. Ms. Rosal did not grade these quizzes; she emphasized that they were for the students' own use and a "check on what you have learned."

She then introduced an experiment suggested in the teacher's guide and described in detail in one of her library books. This experiment is intended to demonstrate the refraction of light by water. A coin that is out of a student's line of sight "appears" when water bends light reflected by the coin, as indicated in Figure 1, below.




Without water: Observer cannot see the coin.

With water: Observer sees the coin.

Figure 1. Path taken by light in the coin demonstration.

Ms. Rosal began the demonstration by reminding the students of a previous demonstration, in which the bending of light caused a pencil to appear bent when it was lowered into a glass of water. She continued,

> The same thing happens here. The light rays are coming down and hitting the water and so at that point, where the light rays change speed because of what they are traveling through, then it makes the difference and we see the bending or the refraction of light. . . (Reading from a library book) "Having read about refraction, lets see it in action. You need some water, a coin and a pan." All right, I happen to have those things here this afternoon. Faith, why don't you be our guinea pig today.

Faith and another student called the "scientific reporter" came to the front of the room. Faith was positioned in a chair about three feet away from a portable cart at the front of the classroom.

Ms. Rosal continued, "It says, 'Lay the coin in the center in the bottom of the pan, then place the pan on the table so you can see the coin.'" Ms. Rosal, with the assistance of the reporter, followed the directions by moving the cart to a position where the coin just disappeared from Faith's sight.

Ms. Rosal asked her students, "Why can she not see the coin now?" Sheila answered, "Because before she could see over it, and now she can't see it when you moved it (the cart) over." Ms. Rosal restated,

> From where she is sitting now, the edge of the pan is sticking up high enough that she can't see it. Now, when I hold up something (she held up a margarine tub with her hand inside of it as she stood near Carol's desk) right here in this tub and I say, "See the little mouse I have in here! See it Carol? Do you like it?" She says "I can't see it, Ms. Rosal, because I can't see over the edge."

The students laughed as Ms. Rosal continued, "If I lower it down or bring it closer she can see it. Right?" She lowered the margarine tub down to Carol's eye level to demonstrate how Carol could then see into the container. She then returned her attention to the experiment at the front of the room.

Ms. Rosal sent a student to get water in a jar from the activity room as she said, "Now, I'm not moving the pan, and I'm not moving the cart. Tell us what happens, Faith." She poured the water into the pan from the jar, then asked Faith if she could see the coin. Faith said yes. Ms. Rosal explained, "not because the pan is going up or the coin floats." (Some students were attributing what happened to the coin being round and floating.)

As Ms. Rosal prepared to repeat the demonstration for Faith, she asked her to explain what happened. Faith said, "The water is going down." At this point, several students had ventured out of their seats to come and see, while others raised their hands and asked if they could come up and see too.

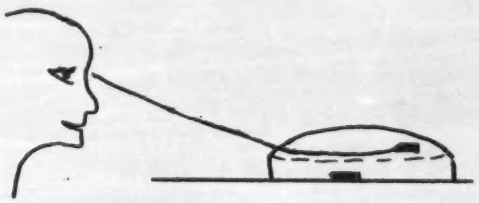
Ms. Rosal told the students to return to their seats, then, as she repeated the demonstration, the following interchange occurred:

> Ms. Rosal: Where is the light coming from that shines on the coin?
>
> Paul: (pointing to the ceiling) The lights.
>
> Ms. Rosal: All right, down from the top. As the light rays hit it where might they be bouncing?
>
> All students: Up.
>
> Ms. Rosal: Just up now? As I add water what might be happening to the light rays?
>
> Rhonda: The light coming down is hitting the pan.
>
> Ms. Rosal: But it was hitting the pan before. What's it hitting now? What's been added that wasn't there before?
>
> Mike: It's hitting the water.
>
> Ms. Rosal: It's hitting the water, and we already said that sometimes the speed of light is going to be changed when it goes through water, and here the speed of light, reflection of the coin, the light reflects from the coin, not necessarily the speed but also the angle of the light. So she is seeing the image of the coin here on the water. The coin hasn't moved but she's seeing the image of the coin on the water.

Ms. Rosal said, "I know what everyone would like to do, I bet," as she directed Faith to return to her seat and Sheila to come up and observe. She ultimately let every student in the class come up, two at a time, to see the coin appear as she added the water. Throughout the process she maintained the students' attention by discussing what was happening to the light and by varying the procedures (such as holding the coin down on the bottom of the pan with a pencil to prove to the inquisitive Jeff that it was not floating). She also made comments about scientists such as, "One thing about a scientist is he must be honest in judgment."

After everyone had had a turn, Ms. Rosal continued, "All right, let me read the rest of this experiment and encourage some of you to do it at home, and maybe we'll try some of the others in here (the library book)," She read the directions again, then read, "Here is what happened. When you moved the pan, its sides prevented reflected light from the coin from reaching your eye." At this point, Ms. Rosal interrupted her reading to draw a picture on the board of the coin in the pan with light rays being reflected (see Drawing No. 1, Figure 2).

Drawing No. 1



Drawing No. 2

Figure 2. Ms. Rosal's drawings of the coin demonstration.

She restated, "When you moved the pan, its sides prevented reflected light from the coin from reaching your eyes, so you could not see it." She continued reading, "When water was added to the pan, the principle of refraction took over. . . . The water caused the light rays from the coin to bend so you again saw the coin." She drew another picture (see Drawing No. 2, Figure 2) to demonstrate this as she stated,

> I had it here in the center of the pan and you were sitting over here (she points where) when you couldn't see it anymore. First, it was close so you could see it--when you couldn't see it anymore. The light rays, we're going to draw them as rays coming off like the cartoons where the car has head lights. You couldn't catch any of those rays in your eye so you couldn't see the image of the coin. The light rays perhaps were bent and moved the image of the coin over here. So now you could pick that up with your eyes. It has moved far enough to the side that you could see it.

Commentary on the Coin Demonstration

This episode again illustrates each of the characteristics of Ms. Rosal's teaching described in the previous commentary. The coin demonstration came in Part 4 of her chapter cycle, and it was followed by Part 5, the chapter review and quiz. The demonstration was ingeneous and very interesting to her students. She adapted her plans as the demonstration proceeded. She had not originally planned, for instance, to let every student see the coin "appear," and she thought of a dramatic way to demonstrate to Jeff that the coin was not floating.

Most apparent from this episode, however, is Ms. Rosal's failure to emphasize the role that reflected light plays in seeing and her apparent personal discomfort with the idea. She began the lesson with the statement that "the edge of the pan is sticking up high enough so that she can't see (the coin)," failing to mention that the edge of the pan blocks the *light* reflected from the coin. Throughout the lesson, the only clear statement that we see reflected light came as she read the book, with her own explanation and drawings appearing confused and contradictory. It was not until the last of her three explanations that she focused on reflected light rather than incident light.

Continuing Instruction

The unit continued in this pattern for another nine lessons. Thus, Ms. Rosal taught a total of 12 lessons on light, totaling about 10 hours (595 minutes). Her final evaluation of the unit was, "I was very pleased with the unit. It went well." She supported her statement by sharing the results from the unit test provided in the teacher's guide. All of the students in her class had received marks higher than 50%, with all except three students receiving 70% or better. Ms. Rosal was confident that her students learned many

new things despite her disatisfaction with he test, which she pointed out had only two questions not taken from Chapter 3.

## Posttest Results

Our own posttest reveled serious problems with student learning. Most students had learned something about transparent, translucent, and opaque objects, and most understood that objects reflect light. However, only eight of the 21 students who took the posttest understood that we see because light reflects off objects to our eyes; the others either clung consistently to their misconceptions or had conflicting answers within their tests, indicating confusion about how we see. Lacking a coherent conception of how we see, most students had serious flaws in their understanding of how our eyes function and of color vision (Anderson & Smith, Note 3).

## Discussion

There were many excellent qualities in Ms. Rosal's teaching. She managed her class well, her demonstrations and discussions were lively and exciting, she gave her students hands-on experiences as well as discussions and reading, she integrated her science teaching with teaching in other subject areas, and related science to her students' personal lives. In spite of this, most of her students ended the unit with a seriously flawed understanding of light and how we see. What went wrong?

We believe that there were two serious problems with Ms. Rosal's teaching.

The first of these was the inadequacy of the Exploring Science text and teacher's guide. The text did not describe how we see in a way that was adequate to alter the ideas of children strongly committed to their misconceptions (Eaton, Anderson & Smith, in press). The teacher's guide did not prepare Ms. Rosal for the existence of those misconceptions or suggest a strategy adequate for

dealing with them. Teachers as qualified and dedicated as Ms. Rosal deserve better.

The second problem lay in Ms. Rosal's approach to teaching and conducting class discussions. Although her discussions were lively and meaningfully related to her students' life experiences, she tended to ask a question, then continue calling on students until some studentcame up with the "correct" answer. She did not use the incorrect answers to diagnose her students' misconceptions, and sometimes (as in the coin demonstration) she seemed to accept student explanations that were substantially incorrect. Because she was only vaguely aware of her students' misconceptions, she failed to provide her students with specific experiences that would help them to alter those misconceptions.

Both of the above problems, however, can be solved. In particular, science program materials can be improved so that they help teachers to understand their students' misconceptions and change them successfully. We are currently developing such materials, and Ms. Rosal is among the teachers helping us to test them.

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